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**ASSESSMENT OF AIRCRAFT IMPACT PROBABILITIES
AT THE IDAHO CHEMICAL PROCESSING PLANT**

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EXECUTIVE SUMMARY

The purpose of this study is to evaluate the possibility of an aircraft crash into a facility at the Idaho Chemical Processing Plant (ICPP). The ICPP is part of the Idaho National Engineering Laboratory (INEL). Based on the data used in this study, an air crash into any single facility at the ICPP is incredible. An air crash into aggregate areas incorporating the following is extremely unlikely: 1) ICPP radiological materials storage facilities, 2) ICPP major processing facilities, and 3) the ICPP land surface area, which excludes buildings.

According to Westinghouse Idaho Nuclear Company safety analysis procedures, if the probability of a radiological release event is determined to be incredible, no further review is required. Therefore, an aircraft crash scenario is not required in the safety analysis for a single facility but should be discussed relative to the ICPP aggregate areas.

The highest probability in the study was for aircraft during Federal Aviation Administration (FAA) test flights at the ICPP to crash into the aggregate area for radiological materials storage facilities. The crash frequency during FAA tests is $7.8 \times 10^{-6}/y$ (or once in about 130,000 years), which is relatively close to the incredible level of $1 \times 10^{-6}/y$. Conducting an FAA test no more than once every five years reduces the probability of an air crash during FAA tests into radiological materials storage facilities to within the incredible range.

Also higher than the incredible range, the probability for Protection Technology Idaho (PTI) helicopters, which provide security flight service for the INEL, to crash while taking off and landing from the ICPP heliport is $1.2 \times 10^{-6}/y$. This probability can be reduced to within the incredible range by 1) restricting the PTI helicopters from taking off and landing in the direction of the ICPP, 2) limiting the number of helicopter flights during takeoffs and landings to no more than 601, and 3) relocating the heliport, which is 3 miles from the ICPP, farther from the plant. The probability for PTI helicopters to crash

into the aggregate area for ICPP major processing facilities is greater than for the ICPP site area, but is only slightly higher than incredible. The probability is incredible for PTI helicopters to crash into the aggregate area for ICPP radiological materials storage facilities while flying directly over the ICPP.

All other local (air taxi) flights that approach close to the ICPP were computed to have probabilities within the incredible range relative to the ICPP.

Two sets of data were used for developing criteria for comparing the calculated probabilities of aircraft collisions with facilities at the ICPP. The first set of data was from the Nuclear Regulatory Commission (NRC). The NRC data provided the method and basic criteria for calculating crash rates. And the NRC set of data were used to evaluate the safety of nuclear power plant locations relative to aircraft crashes. For nuclear power plants with neighboring airports, the accepted rate unit is fatal crashes per square mile. For inflight crash scenarios, a total loss of control crash rate, where the pilot loses all control, is used for evaluating the safety of the nuclear reactors.

The other set of data was obtained from the annual review of the National Transportation Safety Board (NTSB). The NTSB data were used to convert the NRC criteria to match the types of aircraft at the ICPP. These data calculations show higher crash frequencies because crashes in which the pilot maintained some control have been included in the calculations. Including the entire range of crashes increased the applicability of the review data to more types of aircraft. First, the data are categorized by type of aircraft, which allows the computation of the frequencies for specific flight paths. Second, the data are given year by year during a 10-year time span, which illustrates the variability in crash frequencies from one year to another, and allows variability to be factored into the comparison criteria.

The calculations for crashes per unit area from the NRC, modified by the NTSB data, were then applied to the location of the ICPP structures, closeness of flight paths, and frequency of flights.

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1. INTRODUCTION

The Idaho Chemical Processing Plant (ICPP) is located on the Idaho National Engineering Laboratory (INEL) site. The ICPP stores and prepares radiological materials for disposal. The external event of an airplane crash that could allow the release of these materials is a concern in reviewing the existing hazards and when siting new facilities. Such an external issue is just one of the items included in the safety analysis conducted on all facilities. Safety analysis is used to evaluate the hazards at U.S. Department of Energy (DOE) facilities that are not routinely accepted by the public and that may impact those who operate the facility, or the public or the environment that surrounds the facility. DOE Order 5481.1B requires that potential hazards be systematically identified and reviewed. In safety analysis reports, airplane crash potential is discussed when the frequency of impact releasing hazardous agents is high enough to pose a significant hazard. This report supports the safety analysis effort by analyzing the frequency of potential aircraft collisions with ICPP facilities.

The ICPP and potential crash target facilities are discussed in this report first and then air traffic in the surrounding area, including airports, flights, and flight paths. The Nuclear Regulatory Commission (NRC) Standard Review Plan provides the benchmark criteria for the analysis. The inadequacies of the NRC plan are discussed, and estimates are made to apply the plan to the ICPP facility. Further adjustments are made using the National Transportation Safety Board (NTSB) crash statistics to develop accident rates for small air taxi and helicopter aircraft relevant to the ICPP site review. The NRC plan equation was corrected for flight-path width. Estimated from NTSB crash statistics, year-to-year variability was added as it applies to the ICPP situation.

References to NRC original data include only English units of measurement. Metric units or metric equivalents have been provided for all calculations completed for this study.

1.1 ICPP

The ICPP is in the south-central portion of the INEL in Butte County, about 67 km (42 mi) west of Idaho Falls. In 1949, the U.S. Atomic Energy Commission established the INEL as the National Reactor Testing Station (NRTS) for testing various types of nuclear reactors and associated equipment. The INEL is next to the western edge of the Upper Snake River Plain in southeastern Idaho. The INEL contains 2305 km² (890 mi² or 570,000 acres) and has average elevation of 1480 m (4850 ft) above sea level. Figure 1 shows the relative location of the ICPP and the INEL boundary.

The ICPP mission is to receive, store, and prepare many types of spent nuclear fuels for disposal as assigned by the DOE. Until recently, the ICPP processed spent, highly enriched nuclear reactor fuels for recovery of residual uranium. Nuclear liquid waste from that processing is presently converted into solid granules in the New Waste Calcine Facility (NWCf). Liquid and gaseous waste streams from plant equipment are contained and treated to comply with DOE and environmental standards.

The ICPP is remote from major population centers, waterways, and transportation routes. The INEL has no permanent residents, and the ingress and egress are closely controlled of site personnel performing their job duties and of visitors performing official business. No casual visitations are permitted. There are no recreational activities within the INEL, and agriculture consists only of limited grazing. For national security purposes, the INEL has in effect a Federal Aviation Administration (FAA) advisory specifying a flight altitude above 1950 meters (6400 ft) mean sea level (MSL) for aircraft. Aircraft usually fly around the INEL.

The restricted area of the ICPP, which comprises several facilities containing potential release contaminants, encompasses 0.49 km² (0.19 mi² or 120 acres) of the total ICPP area of 0.59 km² (0.23 mi² or 147 acres). The mean elevation of the ICPP where the facilities are located is 1498.6 m (4916.6 ft) above sea level. Materials with release potential

Figure 1. Location of the ICPP

from aircraft crash incidents could include solidified granules of waste in storage, process streams, and waste streams.

The ICPP plant has several areas that factor into plane crash scenarios. The overall restricted area of 0.49 km² (120 acres) is of interest in comparison to the INEL to provide a general likelihood of crash scenarios at future facilities. Specific ICPP structures that are of interest relative to plane impacts are listed in table 1. The main stack is included as a storage area because of the stack's potential of falling into adjacent storage areas after an aircraft impact.

1.2 AIRPORTS

Airports near the INEL include the Idaho Falls Airport (80 km or 50 mi from the INEL), the Pocatello Airport (97 km or 60 mi from the INEL), Burley airport (110 km or 70 mi from the INEL), the Twin Falls Airport (145 km or 90 mi from the INEL), and other agricultural landing strips. Because these airports are a significant distance from the INEL, any flights over the INEL site would be in the inflight or cruise mode of flight.

The Idaho Falls airport has about 45,000 operations a year. Of this, approximately 11,000 operations are for air taxis (small wingspan commercial aircraft), 4000 operations for air carriers (large wingspan commercial aircraft), and 30,000 operations for general aviation (small wingspan noncommercial aircraft). There are four air taxi flights a day between Boise and Idaho Falls. Air taxi flights include two operations a day for five days of the week between Idaho Falls and Salmon.¹

The Pocatello airport averages 52,000 operations a year. General aviation accounts for two-thirds of this number (35,000 operations a year) and air taxis account for one-third (17,000 operations a year). Most of the traffic is to Boise and Salt Lake City.²

The Burley airport maintains aircraft operations and statistics on aircraft flying over the airport. The airport has approximately

Table 1. Crash Targets of Interest for ICPP Facilities

FACILITY	FACILITY DIMENSIONS		
	LENGTH m (ft)	WIDTH m (ft)	HEIGHT m (ft)
ICPP (total area)	914.4 (3000)	548.6 (1800)	NA
CPP-601 Processing Bldg	74.4 (244)	31.1 (102)	11.9 (38)
CPP-602 Lab Bldg	51.8 (170)	44.2 (145)	4.6 (15)
CPP-627 Remote Analytical Facility	26.8 (88)	27.1 (89)	6.4 (21)
CPP-640 Headend Processing	20.1 (66)	27.1 (89)	10.4 (34)
CPP-659 NWCF	76.2 (250)	44.2 (145)	13.1 (43)
CPP-604 Waste Treatment	50.6 (166)	27.4 (90)	12.2 (40)
CPP-605 Waste Treatment	13.7 (45)	19.8 (65)	12.2 (40)
CPP-603 Decon Area South	6.1 (20)	4.6 (15)	11.0 (36)
RADIOLOGICAL MATERIALS STORAGE FACILITIES			
CPP-603 Fuel Receiving & Storage	61.0 (200)	8.8 (29)	11.0 (36)
CPP-603 Storage Basin North and middle	24.4 (80)	18.2 (60)	4.0 (13) (storage underground)
CPP-603 Storage Basin South	13.7 (45)	26.8 (88)	11.0 (36) (storage underground)
CPP-651 Unirradiated Fuel Storage	13.7 (45)	12.8 (42)	4.0 (13) (bermed storage)
CPP-603 Graphite Fuel Storage	25.9 (85)	38.1 (125)	11.0 (36)
CPP-708 Main Stack	6.1 (20)	6.1 (20)	76.2 (250)
CPP-749 Peach Bottom Fuel Storage	109.7 (360)	100.6 (330)	(storage underground)
FAST	133.5 (438)	23.2 (76)	14.6 (48)
Fifth BIN SET	5.2 (17)	5.2 (17)	8.8 (29) (storage underground)
Sixth BIN SET	18.6 (61)	18.6 (61)	19.5 (64) (storage underground)
Seventh BIN SET	18.6 (61)	18.6 (61)	19.5 (64) (storage underground)
Tank Farm Storage Area	173.7 (570)	109.7 (360)	(storage underground)

23,000 operations and aircraft flights over the airport a year. General aviation accounts for 19,000 a year, air taxis account for 3000 a year, air carriers 100 a year, and military flights account for 600 a year.³

The Twin Falls airport averages approximately 45,000 operations a year. General aviation accounts for 32,000 operations a year, air taxis account for 12,000 operations a year, air carriers account for 160 operations a year, and military flights account for 900 operations a year.⁴

Several small gravel-surface landing strips are located near the INEL, the largest of which is in Atomic City, 18 km (11 mi) southeast of the ICPP. Most of the crop-dusting aircraft around the INEL use only the INEL boundary fringe for turning the aircraft. Aircraft do not routinely cross over the site. But a few times a year aircraft must be moved across the site. The INEL Flight Department approves 60 to 100 overflights a year by crop-dusting and other similar aircraft. The flights are too few to impact the results of this report and are not considered a concern.

1.3 AIRWAYS

The types of air traffic near the INEL are air taxi and general aviation. The most significant of the two types are the air taxi flights between Idaho Falls and Boise. These flights cross over the INEL about 5 km (3 mi) south of the ICPP stack. An average of two or three flights a day are made between these two cities for a total of 1000 flights a year.

Air taxi flights from Idaho Falls to Pocatello, Burley, and Twin Falls (registered with the FAA as vector 269) approach to within 30 km (19 mi) of the ICPP. About six flights a day are made for a total of 2000 flights a year.

General aviation flights from Pocatello to Salmon (FAA vector 269) cross the INEL site and are 15 km (9 mi) from the ICPP stack. Very few flights a year travel this path. Aviation flights from Pocatello to

Boise (FAA vector 269) and from Pocatello to Idaho Falls (FAA vector 21) each total 2,000 flights a year.

Military training routes IR 302 and 314 pass within 40 km (25 mi) of the ICPP and pass over the Craters of the Moon National Monument. IR 302 has 800 operations a year, and IR 314 has three operations a year.⁵

The rest of the flight paths are at least 40 km (25 mi) from the INEL site and are not a concern in this report.

1.4 PTI HELICOPTERS

The INEL security helicopters are turbine-powered rotocrafts used to patrol the INEL site boundary and the areas within. Because the helicopters land and take off on-site and patrol the INEL site, 95 percent of the total flight time is over the INEL site. The flight time of the helicopters amounts to a total of 1200 hours each year. For a typical 90-minute flight, the INEL helicopters spend five minutes in takeoff, five minutes in landing, and 80 minutes in flight. Approximately 800 flights are made each year. The helicopter pad is located 5 km (3 mi) from the ICPP.

1.5 FAA AIRCRAFT TESTS

The FAA has tested the air flow pattern of new commercial aircraft at the INEL. The National Oceanic and Atmospheric Administration (NOAA) has a 61-m (200-ft) aluminum tower north of the ICPP, which is used to measure turbulence created by aircraft wings. The test data are used to establish safe distances between aircraft on takeoff and landing.

From September through October of 1990, four new aircraft types were tested: Boeing 767, 757-200, 747-400, and the French Air Bus A300. Flights were from the southcast to northwest and passed the tower on the northeast side. With the craft in landing configuration, each aircraft made 36 passes by the tower for a total of 144 passes.⁶

The NOAA tower is about 2.4 km (1.5 mi) north of the ICPP. Smoke grenades are placed at 11 levels of the tower. As the planes passes, the smoke is entrained in the vortex created by the passing wing. The 200 anemometers on the tower measure the windspeed inside the vortices. Tests have been conducted over the INEL once every three or four years on an as-needed basis since 1970.

2. CRITERIA

The selection criteria that are used in siting nuclear reactors is provided in 10 Code of Federal Regulations (CFR) Part 100, Reactor Site Criteria. The criteria are also used for siting other radiological facilities. Section 100.10 requires a low risk of public exposure.⁷ A similar approach is specified in DOE Orders for nonnuclear facilities. DOE Order 5481.1B requires potential hazards including aircraft impact potentials to be systematically identified and reviewed. Scenarios may be excluded from analysis if the frequency of occurrence is low enough. According to WINCO safety analysis procedures, if the likelihood of an event is less than once in a million years (occurrence frequency of $1 \times 10^{-6}/y$), it is classed as "incredible" and no further review is required.⁸

2.1 BASIC EQUATIONS

The basic equations for calculating aircraft impact frequency per year use accident statistics and apportion the rate according to the area of the impact target building and the area for which the statistics were collected. Statistics collected for accidents around airports are rates with a denominator of a square mile. This is multiplied directly with the target area to obtain the impact frequency for the target.

Statistics used for flight paths and corridors are reported with a denominator of flight miles. The denominator of flight miles used with commercial carrier rates is converted to a denominator of area by dividing the rate by the flight path width (typically 9 miles) and then multiplying by the target area to get the impact frequency for the target. If the target is outside the flight path, the flight width divided into the rate is increased on both sides of the path until the target area is included in the area. This compensates for the aircraft's possible deviation on either side of the flight path. This distance is twice the distance from the center of the flight path to the target area. In each case the denominator units are converted to area units before multiplying by the target area.

The typical flight path rate calculation, which is estimated as a uniform distribution within the 9-mile flight path and with a uniform extension of flight path statistics to targets outside the flight path, is not supported by data. Crash frequency appears to decrease exponentially from the center of the flight path. The typical flight path rate calculation underestimates the rate for the middle of the path and overestimates the rate outside the path. Comparison with an exponential flight path calculation is used to determine the deviation of the NRC calculations from what should be expected.

The NRC Standard Review Plan provides benchmark criteria and methods acceptable in analyzing air crash potential. For example, the plan includes crash frequency statistics around airports and the inflight crash frequency for commercial aircraft acceptable to the NRC. The inflight statistics refer to crashes with total loss of control (TLOC) of the aircraft. Therefore, a controlled crash where the pilot can direct the direction of the crash would not be included as an inflight accident. The airport statistics include only crashes resulting in fatalities. The shortcomings of the plan include an absence of crash rates for airport and inflight noncommercial aircraft and a lack of variability data on the rates provided.

Extrapolation of the NTSB to NRC accident frequencies is used to fill in some of the criteria gaps in the NRC standard review plan. The assumption that TLOC inflight accidents are proportional to NTSB crash statistics is used to estimate TLOC accidents for general aviation and the other categories from the commercial aircraft crash frequency in the NRC plan. The hours per mile ratio is determined from the NTSB data for air carriers and air taxis. The ratio for air taxis is used to convert the general aviation and turbine helicopter data from NTSB accidents per hour to accidents per mile. This is appropriate because the wing spans for the aircraft are approximately the same length. The ratio of air carrier TLOC accidents versus NTSB accidents per mile is used to convert the derived NTSB accident rates for general aviation, turbine helicopters, and air taxis to TLOC accidents per mile.

Tuning the NRC airport frequency rate to specific aircraft like air taxis or helicopters is accomplished by use of derived TLOC accident rates. The relative fractions of complete loss of control of the aircraft is assumed proportional with the NRC airport fatal accidents in determining the airport accident rates for helicopter and air taxi aircraft.

Year-to-year variability of the NRC plan rates is estimated as proportional to the variability of the NTSB year-to-year rates. Specifically, the NTSB coefficient of variations is directly applied to the frequencies obtained from the NRC and NTSB data.

2.2 NRC STANDARD REVIEW PLAN

In reviewing applications of nuclear reactor sites, the NRC uses its Standard Review Plan for reviewing aircraft hazards.⁹ Acceptance criteria for the frequency of aircraft hazards are met if the frequency of aircraft accidents resulting in radiological consequences that are greater than guidelines in 10 CFR Part 100 is less than about 10^{-7} a year (1/10th of the incredible level). This requirement may be met by inspection using proximity criteria or by using frequency calculations in an aircraft hazards assessment.

A proposed reactor site is considered to meet the requirements by inspection if the following criteria are met:

1. The plant-to-airport distance D is between 5 and 10 statute miles and the projected annual number of operations is less than $500 \times D^2$, or the plant-to-airport distance D is greater than 10 statute miles and the projected annual number of operations is less than $1000 \times D^2$;
2. The plant is at least 5 statute miles from the edge of military training routes, including low-level training routes, except those associated with usage greater than 1000 flights a year, or where activities may create an unusual stress situation; and

3. The plant is at least 2 statute miles beyond the nearest edge of a federal airway, holding pattern, or approach pattern.

If a site fails to meet the criteria by inspection, an aircraft hazards assessment is required. The aircraft hazards assessment includes frequency calculations for nearby airways, airports, designated airspaces, and holding patterns.

The accident frequency calculation for an airway for a proposed site, P_{FA} calculated below, is obtained by multiplying the inflight crash rate for the aircraft by the number of trips and by the ratio of the target area with the area under the airway on both sides up to the distance of the target. The crash rate is per flight mile. Dividing the crash rate by the width of the path under the plane gives the crash rate per flight per unit area. If the target plant site is farther than 4.5 miles (half the 9-mile airway width), then the crash rate is further reduced by adding twice the target distance to the path width in the denominator. If the target is within the airway, the width is set at 9 miles. This is a simplification that does not agree with the decreasing exponential distribution of air crash potentials as the distance from the center of the airway increases.

$$P_{FA} = C \times N \times A / w \quad (1)$$

where:

- P_{FA} = airway accident frequency per year,
- C = inflight crash rate per mile for aircraft using the airway,
- w = width of airway plus twice the distance from the airway edge to the site in miles when the site is outside the airway, or width of airway in miles when the site is within the airway,
- N = number of flights per year along the airway, and
- A = effective area of plant in square miles.

A value of $C = 4 \times 10^{-10}$ per aircraft mile is used in the NRC Standard Review Plan for inflight calculations as provided in

congressional testimony.¹⁰ This accident rate is for commercial aircraft en route. It is based on one catastrophic inflight failure occurring in the United States a year. In such an accident the plane will lose altitude with no pilot directional control of the aircraft. No rate is provided for general, military, air taxi, and helicopter air traffic. Crash rates must be estimated for other types of aircraft when applying the NRC plan to these specific aircraft.

Airport accident frequency calculations for civilian, military, and helicopter traffic are determined, as shown below, by multiplying the fatal crash frequency per square mile by the number of flights and the target area for each type of aircraft. The frequency per square mile (C_j) shown in table 2,^{11, 12} varies with the distance from the airport and is specified for general, commercial, and military flights. As the distance from the airport increases, the frequency per square mile decreases. The total frequency, P_A , is the sum of all the flight frequencies:

$$P_A = \sum_{i=1}^L \sum_{j=1}^M C_j \times N_{ij} \times A_j \quad (2)$$

where:

- P_A = airport accident frequency per year,
- M = number of different types of aircraft using the airport,
- L = number of flight paths affecting the site,
- C_j = frequency per square mile of a crash per aircraft movement,
- N_{ij} = number (per year) of movements by the j th aircraft type along the i th flight path, and
- A_j = effective plant area for the j th aircraft type.

Holding patterns outside an airport distance of 5 miles are converted into equivalent inflight aircraft airways taking into account the operations and orientation of the pattern with respect to the target reactor plant.

Table 2. Fatal Crashes per Square Mile per Airport Aircraft Movement

MILES FROM AIRPORT	AIR CARRIER	GENERAL AVIATION	USN & USMC	USAF
1	1.67E-7	8.4E-7	8.3E-8	5.7E-8
2	4.0E-8	1.5E-7	1.1E-8	2.3E-8
3	9.6E-9	6.2E-8	3.3E-9	1.1E-8
4	6.8E-9	3.8E-8	3.1E-9	4.2E-9
5	2.7E-9	1.2E-8	2.0E-9	4.0E-9
6	0	NA	NA	NA
7	0	NA	NA	NA
8	0	NA	NA	NA
9	1.4E-9	NA	NA	NA
10	1.2E-9	NA	NA	NA

2.3 EFFECTIVE TARGET AREA

All of the crash frequency calculations in the standard review plan use a target area that is actually larger than a facility's horizontal cross-sectional area. The target area is an effective impact area (A), which includes: 1) the shadow area from crash angle, 2) the skid area of a plane in front of the target building, 3) the expanded area of the buildings, which accounts for the wing or rotor span of the aircraft, and 4) the horizontal cross-section area of the target affected by aircraft crashes.

The shadow area is the building elevation projected upon the horizontal plane (behind the building from the projected impact). Typically, the crash angle is 20 degrees but varies from 0 to 30 degrees. The shadow area depends upon the assumed crash angle for the various aircraft and the angle of approach relative to the broadside (θ) of the building target. The area is greatest when the angle is straight onto the building's opposite corner diagonal. A facility that is underground or that has no height would not have a shadow area included in the target. A plane passing above the ground would miss a target with no height.

The skid area around the ICPP is different for each type of aircraft. A skid length of 100 m is used for general aviation aircraft and similarly sized aircraft. A length of 500 m is used for commercial aircraft and other large aircraft. Artificial berms or other barriers in the skid area can also be taken into account and may reduce the skid area. A facility that is underground would not be impacted by a plane skidding along the ground.

The expanded area is the area around the top of a facility that accounts for a vehicle's wing span or the tip of the wing hitting the target. The expanded area is larger for large aircraft with long wing spans. A wing span of 12 m (39 ft) is used for general aviation and similarly sized aircraft and a wing span of 60 m (200 ft) for commercial and similarly sized aircraft.

The target areas are the safety-related parts of the target that are susceptible to impact or fire damage as a result of aircraft crashes. This area is typically the horizontal cross-sectional footprint of the building.

The aircraft effective crash area is based upon the sum of three area factors. First is the shadow area.

$$A_{\text{shadow}} = h \cdot \left(\frac{w_{\text{large}} \cdot \cos(-\theta) - w_{\text{small}} \cdot \sin(-\theta) + 2 \cdot \frac{\text{span}}{2}}{\tan(\phi)} \right) \quad (3)$$

where:

- θ = the angle from the building broadside as the plane approaches the target
- h = the height of the facility
- w = the length of the sides of the facility
- ϕ = the angle of impact measured from the horizon
- span = the aircraft wing span

Next is skid area in which the distance that an aircraft may skid and reach a building is accounted for.

$$A_{skid} = d \cdot \left(w_{large} \cdot \cos(-\theta) - w_{small} \cdot \sin(-\theta) + 2 \cdot \frac{span}{2} \right) \quad (4)$$

where:

d = distance this type of aircraft is expected to skid

(The other variables have been defined previously.)

Third is the expanded area that includes the length of the aircraft wings.

$$A_{expanded} = (w_{large} \cdot w_{small}) + 2 \cdot \frac{span}{2} (w_{small} \cdot \cos(-\theta) - w_{large} \cdot \sin(-\theta)) \quad (5)$$

(The variables have been defined previously.)

The effective impact area equals the sum of the shadow area, the skid area, and the expanded area.

$$A = A_{shadow} + A_{skid} + A_{expanded} \quad (6)$$

This area is used as the A in the airway accident frequency calculation and used as the A_i in the airport accident frequency calculation.

3. CORRECTIONS TO THE NRC STANDARD REVIEW PLAN

The following sections estimate and extrapolate to fill the gaps in the NRC Standard Review Plan needed to evaluate the ICPP air crash potential. The inflight crash rates for air taxis and turbine helicopters are missing for TLOC crashes in flight. Also crash rates for airport scenarios for air taxis and turbine helicopters are missing. These inadequacies are addressed by the following steps.

1. Determining the inflight crash frequencies for general aviation, air taxis, and for turbine helicopters from the air carrier TLOC crash rate using NTSB data,
2. Determining the airport fatal accident rates for air taxi and turbine helicopters using derived TLOC rates,
3. Adding the year-to-year variability from NTSB data and applying it to the NRC derived rates, and
4. Correcting the flight path for decreasing exponential crashes as the target distance from the center of the flight path increases.

3.1 INFLIGHT FREQUENCY RATES FOR GENERAL AVIATION, AIR TAXIS, AND TURBINE HELICOPTERS

The NTSB accident data source was used to develop ratio correction factors and crash frequencies for general aviation, air taxis, and turbine helicopters because it has accident statistics segregated in these categories. The NTSB also has several years of data available for estimating the data variability. A larger data base is used in the NTSB rates by including all fatal accidents instead of just the inflight TLOC aircraft crashes as used in the NRC Standard Review Plan. Therefore, a direct comparison of accident rates cannot be made. Ratios between subgroups of data within the NTSB data and, of importance to the ICPP crash frequency determination, the TLOC rates are assumed to be

consistent for determining the crash frequency for general aviation, air taxis, and turbine helicopters.

The NTSB tabulates and publishes aircraft accident rates on a periodic basis. Annual reviews are published for U.S. commercial carrier operations¹³ and for U.S. general aviation.¹⁴ The air carrier information is collected for air taxis, nonscheduled air taxis, and air carriers. The general aviation information is collected for general aviation, fixed-wing, and rotocraft types of aircraft. The statistics collected include groupings of unscheduled landings, property damage, serious injury, and fatal accidents. Fatal accidents are used in this section for use in aircraft impact frequency calculations.

Table 3 contains NTSB statistics for air carriers. The total accidents are used to calculate the fatal accident rate. The table contains the total fatal accidents, the numbers of hours and miles flown, and the tabulated fatal accidents per flight hours for air carrier and air taxi operations. The air taxi fatal accident rate is about eight times greater than the rate for air carriers. The ratio of operating hours to flight miles is 5.50 for air taxis and 2.47 for air carriers. This ratio is used to determine the inflight TLOC accident rate for air carriers, general aviation, and turbine helicopters.

Table 4 contains statistics for general aviation accidents. The NTSB data does not provide the accident rate per miles flown as in the air carrier data. The table contains the fatal accident rates per flight hours for general aviation types of aircraft. The rotocraft and fixed wing aircraft have about the same accident rates. The turboprop, turbojet, and turbine rotocraft have the lowest accident rates.

Table 5 contains the extrapolated TLOC crash rates for general aviation, air taxis, and turbine helicopters calculated from the NTSB rates and the air carrier rate of 4×10^{-10} /mi flown. Because the NRC did not provide TLOC crash rates for air taxis, general aviation aircraft, and turbine helicopters, these values were calculated from the NTSB data. The miles-per-hour ratio from the air taxi NTSB data was used

Table 3. Air Carrier Fatal Accidents per Flight Hours

	AIR TAXI	NONSCHEDULED AIR TAXI	AIR CARRIER
ALL ACCIDENTS	19	96	29
FATAL ACCIDENTS	2	27	3
FATAL INFLIGHT LOSS OF CONTROL	1	7	1
FLIGHT HOURS	2,085,285	2,841,717	11,141,531
FATAL ACCIDENTS PER HOUR	9.59E-7	9.50E-6	2.69E-7
MILES FLOWN	378,802	NOT AVAILABLE	4,503,554
FATAL ACCIDENTS PER MILES FLOWN	5.28E-6	NOT AVAILABLE	6.66E-7
RATIO OF HOURS TO MILES	5.50	NA	2.47

Table 4. General Aviation Fatal Accidents by Type of Aircraft

	TYPE OF AIRCRAFT								
	GENERAL AVIATION	ALL FIXED WING	SINGLE ENGINE	MULTI- PLE ENGINE	TURBO- PROP	TURBO- JET	ALL ROTO- CRAFT	RECI- PROCA- TING ROTO- CRAFT	TURBINE ROTO- CRAFT
ALL AC- CIDENTS	2,354	2,104	1,930	148	23	7	180	116	64
FATAL AC- CIDENTS	455	421	348	60	9	4	21	16	5
FATAL IN- FLIGHT LOSS OF CONTROL	135	128	99	19	3	2	7	7	0
FLIGHT HOURS (1000)	29,634	27,067	21,169	3,001	1,416	1,481	1,953	569	1,384
FATAL AC- CIDENTS PER HOURS	1.54E-5	1.56E-5	1.64E-5	2.00E-5	6.36E-6	2.70E-6	1.08E-5	2.81E-5	3.61E-6

Table 5. Total Loss of Control Crash Rates

	AIR CARRIER	AIR TAXI	GENERAL AVIATION	TURBINE HELICOPTER
FATAL CRASHES PER HOUR	2.69E-7	9.59E-7	1.54E-5	3.61E-6
HOURS PER MILE RATIO	2.47	5.50	5.50	5.50
FATAL CRASH RATE PER MILES FLOWN	6.7E-7	5.3E-6	8.5E-5	2.0E-5
TLOC CRASH RATE PER MILE	4.0E-10	3.2E-9	5.1E-8	1.2E-8
RATIO OF TLOC TO FATAL	6.0E-4	6.0E-4	6.0E-4	6.0E-4

to calculate the fatal crash rates per miles flown for general aviation aircraft and turbine helicopters because they are similar to the air taxi in size and have similar lengths of wings or rotors. The TLOC crash rates per mile for air taxis, general aviation aircraft, and turbine helicopters were calculated by dividing each aircraft's fatal accident rate per mile by the air carrier's fatal accident per mile and multiplying by the $4 \times 10^{-10}/\text{mi}$. This produces a TLOC crash rate for each aircraft that has a 6.0×10^{-4} ratio of TLOC to fatal crash rate per mile.

Because the TLOC rate cannot be verified by accident statistics, a regression analysis was conducted to verify use of the calculated TLOC crash rates for the various aircraft. For each type of aircraft three categories of accidents were used: all accidents, fatal accidents, and inflight loss of control accidents. The accidents in these categories were divided by all accidents for each type of aircraft, as shown in table 6. The various aircraft accident ratios were paired to the air carrier accident ratios and then analyzed with regression. The regression intercept was forced to go through zero because all aircraft data corresponding to a zero aircraft ratio should be zero. The high R Squared value, a correlation coefficient, indicates that the regression line has a high correlation, explaining about 93% of the variability for the ratios, as shown in table 7. The X coefficient of 1.016 indicates

Table 6. Fatal, Loss of Control Inflight, and Total Loss of Control Accidents, and Total Loss of Control to Fatal Accidents

	AIR TAXI	NON-SCHEDULED AIR TAXI	AIR CARRIER
ALL ACCIDENTS	1	1	1
FATAL ACCIDENTS	0.11	0.28	0.10
LOSS OF CONTROL INFLIGHT	0.05	0.07	0.03
TLOC	6.3e-5	1.7e-4	6.2e-5
RATIO OF TLOC TO FATAL	6.0E-4	6.0E-4	6.0E-4

	GENERAL AVIATION	ALL FIXED WING	SINGLE ENGINE	MULTIPLE ENGINE	TURBO- PROP	TURBO- JET
ALL ACCIDENTS	1	1	1	1	1	1
FATAL ACCIDENTS	0.19	0.20	0.18	0.41	0.39	0.57
LOSS OF CONTROL INFLIGHT	0.06	0.06	0.05	0.13	0.10	0.29
TLOC	1.2e-4	1.2e-4	1.1e-4	2.4e-4	2.3e-4	3.4e-4
RATIO OF TLOC TO FATAL	6.0E-4	6.0E-4	6.0E-4	6.0E-4	6.0E-4	6.0E-4

	ALL ROTOCRAFT	RECIPROCA- TING ROTOCRAFT	TURBINE ROTOCRAFT
ALL ACCIDENTS	1	1	1
FATAL ACCIDENTS	0.12	0.14	0.08
LOSS OF CONTROL INFLIGHT	0.04	0.06	0
TLOC	7.0e-5	8.3e-5	4.7e-5
RATIO OF TLOC TO FATAL	6.0E-4	6.0E-4	6.0E-4

Table 7. Regression Output of Log of Accident Ratios to Log of Air Carrier Ratios

Constant	0
Std Err. of Y Est.	0.111
R Squared	0.926
No. of Observations	44
Degrees of Freedom	43
X Coefficient(s)	1.016
Std Err of Coef.	0.033

little change in the TLOC value and thus little change in the ratio of TLOC is shown in table 5. The regression results indicate the crash rates in table 5 are appropriate for TLOC frequency calculations.

3.2 AIRPORT CRASH RATES FOR AIR TAXIS AND TURBINE HELICOPTERS

Table 8 contains the calculated airport fatal crash rate for air taxis and turbine helicopters. Because these rates were not provided in the NRC data, they were calculated using the TLOC crash rates in table 5. The air carrier and general aviation aircraft fatal crash rates were copied from table 2. The rate for each distance in table 8 for air taxis and helicopters was calculated by interpolating the values between the air carrier and general aviation aircraft, using the relative values of TLOC rates in table 5. This places the airport crash rates for air taxis and turbine helicopters proportionally between the rates for air carriers and general aviation aircraft, which matches the relative order of the TLOC rates in table 5.

Table 8 contains the calculated airport fatal crash rate for air taxis and turbine helicopters. The rates were calculated such that the air taxi rate is proportionally between the air carrier and general aviation rates and the air carrier TLOC crash rate is between the two rates in table 5. The turbine helicopter fatal crash rates in table 8 are proportionally higher than the air carrier and general aviation rates and the turbine helicopter rate is above the other two for TLOC rates in table 5.

Table 8. Calculated Airport Crash Rate for Air Taxis and Turbine Helicopters

DISTANCE FROM END OF RUN WAY (MILES)	FATAL CRASHES PER SQUARE MILE PER AIRCRAFT MOVEMENT			
	AIR CARRIER	AIR TAXI	GENERAL AVIATION	TURBINE HELICOPTER
0-1	1.7E-7	2.0E-7	8.4E-7	3.2E-7
1-2	4.0E-8	4.6E-8	1.5E-7	6.5E-8
2-3	9.6E-9	1.3E-8	6.2E-8	2.2E-8
3-4	6.8E-9	8.5E-9	3.8E-8	1.4E-8
4-5	2.7E-9	3.2E-9	1.2E-8	4.8E-9

3.3 YEAR-TO-YEAR VARIABILITY ESTIMATES OF ACCIDENT RATES

Tables 9 and 10 list the accident rates per hour flying for the kinds of flying for air carriers and kinds of flying and type of aircraft for U.S. general aviation. The accident rates in table 9 show that the air taxi rate has a decreasing accident trend. Nonscheduled and air carrier rates have remained about the same during the years listed.

If the variance is consistent for the NTSB and NRC type of data, the standard error of the mean divided by the mean can be applied to the calculated NRC crash rates to determine the upper limit on the mean accident rate.

Table 10 contains the fatal accident rates per flight hour by year for general aviation types of aircraft. The accident rates for types of aircraft do not show a changing trend in the rates. The standard error of the mean divided by the mean contains the year-to-year variability used to develop the upper limit on the mean accident rate.

Tables 11 and 12 have the TLOC-per-mile mean accident rates from table 5 and the upper limit for the accident rates. The yearly variability of the mean rate will be below the upper limit of the accident rate 90 percent of the time. The year-to-year variability is determined by using the $t = 1.833$ for the Student's t distribution with 9 degrees of freedom and a 90% confidence level, which means that 10% of

Table 9. Air Carrier Fatal Accidents per Aircraft Hour by Year

YEAR	KINDS OF FLYING		
	AIR TAXI	NONSCHEDULED AIR TAXI	AIR CARRIER
88	9.6E-7	9.5E-6	1.8E-7
87	5.2E-6	1.0E-5	3.8E-7
86	1.2E-6	1.1E-5	2.0E-7
85	4.0E-6	1.3E-5	8.0E-7
84	4.0E-6	7.5E-6	1.2E-7
83	1.3E-6	1.1E-5	5.5E-7
82	3.9E-6	9.5E-6	5.7E-7
81	7.3E-6	1.4E-5	5.6E-7
80	6.8E-6	1.3E-5	1.4E-7
79	1.3E-5	8.1E-6	7.3E-7
MEAN	4.7E-6	1.1E-5	4.2E-7
STANDARD DEVIATION	3.6E-6	2.0E-6	2.5E-7
STANDARD ERROR OF THE MEAN ($s_{\bar{x}}$)	1.1E-6	6.4E-7	8.0E-8
$s_{\bar{x}}$	0.24	0.06	0.19
$\bar{x}$			

Table 10. General Aviation Fatal Accidents per Aircraft Hour by Year

YEAR	GENERAL AVIA- TION	ALL FIXED WING	SINGLE ENGINE	MULTI- PLE ENGINE	TURBO- PROP	TURBO- JET	ALL ROTO- CRAFT	RECIPRO- CATING ROTO- CRAFT	TURBINE ROTO- CRAFT
88	1.5E-5	1.5E-5	1.6E-5	2.0E-5	6.4E-6	2.7E-6	1.1E-5	2.8E-5	3.6E-6
87	1.5E-5	1.5E-5	1.6E-5	1.4E-5	6.4E-6	4.4E-6	1.8E-5	2.5E-5	1.2E-5
86	1.6E-5	1.6E-5	1.7E-5	1.5E-5	8.9E-6	2.1E-6	2.3E-5	2.7E-5	2.0E-5
85	1.6E-5	1.6E-5	1.7E-5	1.8E-5	1.2E-5	3.4E-6	2.1E-5	2.2E-5	2.1E-5
84	1.7E-5	1.7E-5	1.8E-5	1.9E-5	7.1E-6	3.8E-6	2.4E-5	3.8E-5	1.6E-5
83	1.8E-5	1.7E-5	1.9E-5	1.9E-5	6.8E-6	2.8E-6	2.2E-5	3.5E-5	1.5E-5
82	1.8E-5	1.8E-5	2.0E-5	1.9E-5	5.9E-6	1.5E-6	2.5E-5	3.5E-5	2.0E-5
81	1.8E-5	1.8E-5	1.9E-5	1.9E-5	1.1E-5	3.0E-6	1.3E-5	2.4E-5	6.3E-6
80	1.7E-5	1.7E-5	1.7E-5	2.2E-5	7.2E-6	2.4E-6	2.1E-5	3.1E-5	1.5E-5
79	1.3E-5	1.6E-5	1.6E-5	2.1E-5	1.0E-5	2.7E-6	2.2E-5	2.3E-5	2.0E-5
MEAN	1.7E-5	1.6E-5	1.7E-5	1.9E-5	8.2E-6	2.9E-6	2.0E-5	2.9E-5	1.5E-5
STANDARD ERROR	1.2E-6	1.1E-6	1.3E-6	2.5E-6	2.1E-6	8.3E-7	4.7E-6	5.8E-6	5.9E-6
STANDARD ERROR OF THE MEAN ($s_{\bar{x}}$)	3.7E-7	3.6E-7	4.0E-7	8.0E-7	6.7E-7	2.6E-7	1.5E-6	1.8E-6	1.9E-6
$s_{\bar{x}}$ $\bar{x}$	0.022	0.022	0.023	0.042	0.082	0.092	0.074	0.064	0.127

Table 11. Calculated Total Loss of Control Crash Rate Including Year-to-Year Variability

	TOTAL LOSS OF CONTROL CRASHES PER KM (MI) TRAVELED			
	AIR CARRIER	AIR TAXI	GENERAL AVIATION	TURBINE HELICOPTER
TOTAL LOSS OF CONTROL CRASH RATE PER KM (MI)	2.5e-10 (4.0e-10)	2.0e-09 (3.2e-09)	3.2e-08 (5.1e-08)	7.4e-09 (1.2e-08)
TOTAL LOSS OF CONTROL CRASH RATE PER KM (MI) UPPER RATE	3.3e-10 (5.4e-10)	2.8e-09 (4.6e-09)	3.3e-08 (5.3e-08)	9.1e-09 (1.5e-08)

Table 12. Calculated Airport Crash Rate Including Year-to-Year Variability

DISTANCE FROM END OF RUNWAY KM (MI)	FATAL CRASHES PER AIRCRAFT MOVEMENT PER KM ² (PER MI ²)							
	AIR CARRIER	UPPER RATE	AIR TAXI	UPPER RATE	AVIATION	UPPER RATE	HELI-COPTER	UPPER RATE
0-1.6 (0-1)	6.4E-8 (1.7E-7)	8.7E-8 (2.2E-7)	7.9E-8 (2.0E-7)	1.1E-7 (2.9E-7)	3.2E-7 (8.4E-7)	3.4E-7 (8.7E-7)	1.2E-7 (3.2E-7)	1.5E-7 (4.0E-7)
1.6-3.2 (1-2)	1.5E-8 (4.0E-8)	2.1E-8 (5.4E-8)	1.8E-8 (4.6E-8)	2.6E-8 (6.6E-8)	5.8E-8 (1.5E-7)	6.0E-8 (1.6E-7)	2.5E-8 (6.5E-8)	3.1E-8 (8.0E-8)
3.2-4.8 (2-3)	3.7E-9 (9.6E-9)	5.0E-9 (1.3E-8)	4.8E-9 (1.2E-8)	6.9E-9 (1.8E-8)	2.4E-8 (6.2E-8)	2.5E-8 (6.5E-8)	8.3E-9 (2.2E-8)	1.0E-8 (2.7E-8)
4.8-6.4 (3-4)	2.6E-9 (6.8E-9)	3.5E-9 (9.2E-9)	3.3E-9 (8.5E-9)	4.7E-9 (1.2E-8)	1.5E-8 (3.8E-8)	1.5E-8 (4.0E-8)	5.4E-9 (1.4E-8)	6.6E-9 (1.7E-8)
6.4-8 (4-5)	1.0E-9 (2.7E-9)	1.4E-9 (3.6E-9)	1.2E-9 (3.2E-9)	1.8E-9 (4.6E-9)	4.6E-9 (1.2E-8)	4.8E-9 (1.2E-8)	1.9E-9 (4.8E-9)	2.3E-9 (6.0E-9)

the most extreme values in the study have been excluded. The maximum probability is calculated by adding the following variability from the crash rate:

$$\text{upper rate} = \text{mean crash} + (t_9) \times (\text{mean crash rate}) \times \left(\frac{s \bar{x}}{\bar{x}} \right) \quad (7)$$

The calculated TLOC crash rates including the averages and upper limits are listed in table 11. The airport crash rates including averages and upper limits are listed in table 12. The use of the upper limit for the crash rate removes the concern of year-to-year variability of the rate in accident analysis.

3.4 COMPARISON OF PATH CALCULATIONS USING EXPONENTIAL CRASH DISTRIBUTION

The flight path width used in the NRC frequency calculation provides a conservative cushion if the target is near the edge of or outside of the flight path. If the target is at the center of the flight path, the frequency calculated is understated. This is because of 1) assigning the total accidents to the flight path area used in the calculation even though accidents also occur outside the flight path and 2) assigning accident rates to the flight path uniformly even though accidents will decrease as the distance from the center of the path increases.

Total accidents are assigned to the flight path because reporting requirements begin with the first indication of problems, which is generally before the plane deviates from its flight path. The principle that accidents decrease as the distance from the flight path increases is used to screen potential flight paths for consideration for accident analysis as mentioned in section 2.2. If the target site is farther than a few miles from commercial airways or military airways, then it is not considered significant.

Accidents occur outside the flight path, but they are distributed at a decreasing rate from the center of the flight path. Thus a target directly under a flight path would have a greater accident exposure than a target four or five miles from the center of the flight path. Solomon¹⁵ characterized the spread by a decreasing exponential distribution that predicts the impact as the distance increases from the center of the flight path. The equation is used for distances up to 8 miles from the center of the flight path, with the distribution shown in figure 2.

$$f(d) = \frac{1}{2} \gamma \cdot \exp(-\gamma \cdot |d|) \quad (8)$$

where

- γ = 1.6/mile for air carrier, 1/mile for military, and 2/mile for general aviation including air taxi
- d = the distance from the flight path, miles
- $f(d)$ = density with units per mile

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Figure 2. Impact Distribution

This distribution can be used to correct the NRC flight path calculations relative to the target facility location in the flight path.

Tables 13 and 14 and figure 3 contain the comparisons of the values obtained by the two methods for the values of gamma associated with air carriers and general aviation. At about 1 mile from the center of the airway (1.24 miles for air carrier and 1.1 miles for general aviation), the Solomon distribution is equal to the width calculation. Distributions of accidents within the equivalent distances are much greater for the Solomon distribution, indicating that the width calculation method is not conservative within 1 mile of the center of the flight path. Outside of the 1-mile distance, the width calculation overestimates the number of accidents. The Solomon distribution decreases rapidly outside the airway, supporting the use of the screen test using the distance from a flight path.

For the ICPP, use of the width calculation provides a conservative number. The flight path from Idaho Falls to Boise is 5 km (3 mi) from the ICPP. Therefore, the flight path calculates a conservative factor 45 times greater than should be expected for a small aircraft as shown in table 14. The flight path from Idaho Falls to Pocatello, Burley, and Twin Falls is 30 km (19 mi) from the ICPP, calculating to a crash probability for a 13-km (8-mi) distance of more than 5.6×10^5 times greater than should be expected. General aviation flights from Pocatello to Salmon are about 14.5 km (9 mi) from the ICPP, and the probability is more than 5.6×10^5 times greater than should be expected.

For the PTI helicopter, using the airway equation to calculate crash probabilities would underpredict if the flight path were within 1 mile of the ICPP. This underprediction would range from being equal at 1 mile to about 10 percent of what should be expected if the helicopter flew over the ICPP.

**Table 13. Comparison of Solomon's Exponential Distribution with
Airway Width GAMMA = 1.6 (AIR CARRIERS)**

	DISTANCE FROM AIRWAY CENTER (MILES)	AIRWAY WIDTH EQUATION	SOLOMON'S EQUATION	SOLOMON'S /AIRWAY WIDTH EQUATION	AIRWAY WIDTH /SOLOMON'S EQUATION
EQUATIONS EQUAL > FAA TESTS >*	0	0.11	8.0E-1	7.2E+0	1.4E-1
	1	0.11	1.6E-1	1.5E+0	6.9E-1
	1.1	0.11	1.4E-1	1.2E+0	8.1E-1
	1.24	0.11	1.1E-1	9.9E-1	1.0E+0
	1.5	0.11	7.3E-2	6.5E-1	1.5E+0
	2	0.11	3.3E-2	2.9E-1	3.4E+0
AIRWAY BOUNDARY >	3	0.11	6.6E-3	5.9E-2	1.7E+1
	4	0.11	1.3E-3	1.2E-2	8.4E+1
	4.5	0.11	6.0E-4	5.4E-3	1.9E+2
	5	0.10	2.7E-4	2.7E-3	3.7E+2
	6	0.08	5.4E-5	6.5E-4	1.5E+3
	6.5	0.08	2.4E-5	3.2E-4	3.2E+3
LIMIT OF APPLICATION >	7	0.07	1.1E-5	1.5E-4	6.5E+3
	8	0.06	2.2E-6	3.5E-5	2.8E+4
	9	0.06	NA	NA	NA
	9.5	0.05	NA	NA	NA
	10	0.05	NA	NA	NA

* Denotes ICPP calculation.

Table 14. Comparison of Solomon's Exponential Distribution with Airway Width, GAMMA = 2 (GENERAL AVIATION AND AIR TAXIS)

	DISTANCE FROM AIRWAY CENTER (MILES)	AIRWAY WIDTH EQUATION	SOLOMON'S EQUATION	SOLOMON'S /AIRWAY WIDTH EQUATION	AIRWAY WIDTH /SOLOMON'S EQUATION
PTI HELICOPTER >*	0	1.1E-1	1.0E+0	9.0E+0	1.1E-1
	1	1.1E-1	1.4E-1	1.2E+0	8.2E-1
EQUATIONS EQUAL >	1.1	1.1E-1	1.1E-1	1.0E+0	1.0E+0
	1.24	1.1E-1	8.4E-2	7.5E-1	1.3E+0
	1.5	1.1E-1	5.0E-2	4.5E-1	2.2E+0
	2	1.1E-1	1.8E-2	1.6E-1	6.1E+0
PTI HELICOPTER >*	3	1.1E-1	2.5E-3	2.2E-2	4.5E+1
	4	1.1E-1	3.4E-4	3.0E-3	3.3E+2
AIRWAY BOUNDARY >	4.5	1.1E-1	1.2E-4	1.1E-3	9.0E+2
	5	1.0E-1	4.5E-5	4.5E-4	2.2E+3
	6	8.3E-2	6.1E-6	7.4E-5	1.4E+4
	6.5	7.7E-2	2.3E-6	2.9E-5	3.4E+4
	7	7.1E-2	8.3E-7	1.2E-5	8.6E+4
LIMIT OF APPLICATION >	8	6.3E-2	1.1E-7	1.8E-6	5.6E+5
	9	5.6E-2	NA	NA	NA
	9.5	5.3E-2	NA	NA	NA
	10	5.0E-2	NA	NA	NA

* Denotes ICPP Calculation.

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Figure 3. Impact Distribution Versus Width Calculation

4. CALCULATIONS FOR THE ICPP

The calculations using the NRC screening and frequency equations are presented in this section for the ICPP. Screening tabulations, frequency calculations for the ICPP site, and building targets within the ICPP are presented.

4.1 NRC SCREENING CALCULATIONS FOR THE ICPP

The NRC screening calculations for the ICPP compare the number of nearby airport operations and airway distances from the ICPP site with NRC criteria. For the specified distance from the airport or flight path the NRC operations per year must not be exceeded for the ICPP site to pass the screening test.

Table 15 contains the distance of each airport from the ICPP, the operations per year at each airport, the NRC threshold operations per year, and the airport distance criteria for aircraft hazard consideration. The PTI helicopters have been added to the table for comparison because of the close proximity to the ICPP of the landing and takeoff pad. The FAA aircraft tests are included because the aircraft are flown in a landing configuration past the NOAA tower. For all airports, the number of operations per year is less than the NRC threshold. The conclusion from the screening comparison is that flights from nearby airports would not affect the probability of a plane crash at the ICPP. This conclusion applies to all general aviation including flights from these airports that fail to follow air corridors and flight paths.

The PTI helicopters and the FAA aircraft tests, unlike the airports, are too close to the ICPP to be excluded by the screening criteria and must be considered in frequency calculations.

Air corridors and flight paths are considered separately from the airport review. The NRC airway screen criteria for the various airways close to the ICPP are presented in table 16. The commercial airways listed are all farther than the 3-km (2-mi) threshold criterion for

Table 15. Nuclear Regulatory Commission Screening Calculation for ICPP Exposure

AIRPORT	DISTANCE FROM ICPP IN KM (MI)	OPERATIONS PER YEAR	NRC SCREEN OPERATIONS PER YEAR	NRC DISTANCE FROM AIRPORT KM (MI)
IDAHO FALLS	80 (50)	45,000	2,500,000	≥ 16 (10)
POCATELLO	97 (60)	52,000	3,600,000	≥ 16 (10)
BURLEY	110 (70)	23,000	4,900,000	≥ 16 (10)
TWIN FALLS	145 (90)	45,000	8,100,000	≥ 16 (10)
PTI HELICOPTER	5 (3)	800	NA	< 8 (5)
FAA AIRCRAFT TESTS	2.5 (1.5)	288*	NA	< 8 (5)

* Each FAA aircraft passes by the ICPP twice for each test.

Table 16. Nuclear Regulatory Commission Screening Calculation for ICPP Exposure Airways

AIRWAYS	DISTANCE FROM ICPP KM (MI)	OPERATIONS PER YEAR	NRC THRESHOLD DISTANCE KM (MI)	NRC OPERATIONS PER YEAR CRITERIA
IDAHO FALLS - BOISE	5 (3)	1,000	3.2 (2)	NL
POCATELLO - SALMON	14.4 (9)	2,000	3.2 (2)	NL
IDAHO FALLS - POCATELLO - BURLEY - TWIN FALLS	30.4 (19)	2,000	3.2 (2)	NL
MILITARY PATH IR 302/314	40 (25)	3	8 (5)	1000
PTI HELICOPTER	0 (0)	800	3.2 (2)	NL
PTI HELICOPTER	5 (3)	800	3.2 (2)	NL
FAA AIRCRAFT TESTS	2.5 (1.5)	288*	3.2 (2)	NL

NL = No limit
Each FAA aircraft passes by the ICPP twice for each test.

hazard analysis. The military paths are farther than 8 km (5 mi) and have fewer than 1000 flights a year. Even though the flight from Idaho Falls to Boise is not an air corridor, it has been included in the airway list because the path is used by scheduled air taxis on a daily basis.

The PTI helicopters flying over the ICPP and the FAA aircraft tests in the table do not meet the screening criteria. Both are closer than the 2-mi criterion. The operation per year in the table for the FAA aircraft tests is determined as twice the 144 passes by the NOAA tower

because the aircraft must return for each flight that passes by the tower. The conclusion from the NRC screening of the airways nearby the ICPP site is that only the PTI helicopters and the FAA aircraft tests are a concern. Based on the NRC screening, the airways are not a concern because of their distance from the ICPP site and the low usage.

4.2 NRC FREQUENCY CALCULATIONS FOR THE ICPP

The tabulation of the frequency of aircraft accidents as done in an aircraft hazards assessment using NRC statistics provides an impact frequency that can be used to compare different flights as well as provide an overall impact frequency for ICPP impact scenarios. The restricted ICPP area of 0.49 km² (0.19 mi²) is used for the initial crash rate determinations. Only the PTI helicopters and FAA test flights are included in the calculation. The rate for the PTI helicopters is tabulated for both airport and airway because of their takeoffs and landings on the ICPP site and their travel near the ICPP site.

The NRC airway calculations were tabulated for the PTI helicopters and the FAA aircraft tests as shown in table 17 using the extrapolated inflight crash rates presented in section 3.4. The PTI helicopters are included in the table because of the aircrafts possibly flying adjacent to the ICPP site. A comparison of the values with the incredible value of 1×10^{-6} accidents per year indicates that the rate for the PTI helicopters is too great to exclude from the calculations. But the FAA aircraft tests for NRC calculations are incredible and can be excluded.

Table 18 lists airport calculations for the PTI helicopters and FAA aircraft tests using the NRC frequency statistics. The frequency of the PTI helicopters uses the extrapolated airport crash rates presented in section 3.3 of this document. The crash rates for both 3.2 to 4.8 km (2 to 3 mi) and 4.8 to 6.4 km (3 to 4 mi) distances from the airport, taken from table 12, are presented in the table for the PTI helicopters. The PTI helicopters and FAA aircraft tests are bordering on the incredible and cannot be dismissed.

Table 17. Nuclear Regulatory Commission Airway Frequency Calculations for the ICPP

AIRWAY	DISTANCE TO ICPP PER KM (MI)	OPERATIONS PER YEAR [N]	ICPP AREA PER KM ² (MI ²) [A]	FLIGHT WIDTH PER KM (MI) [W]	UPPER BOUND TLOC CRASH RATE PER KM (PER MI) [C]	EXPONENTIAL PATH CORRECTION [S]	UPPER BOUND FREQUENCY PER YEAR [C*S*N*A/W]
PTI HELICOPTERS OVER ICPP	0 (0)	800	0.49 (0.19)	14 (9)	9.1E-9 (1.5E-8)	9	2.2E-6
PTI HELICOPTERS AT LANDING PAD	4.8 (3)	800	0.49 (0.19)	14 (9)	9.1E-9 (1.5E-8)	2.2E-2	5.5E-9
FAA AIRCRAFT TESTS	2.4 (1.5)	288	0.49 (0.19)	14 (9)	3.3E-10 (5.4E-10)	6.5E-1	2.1E-9

Table 18. Nuclear Regulatory Commission Airport Frequency Calculations for the ICPP

AIRPORT SCENARIO	DISTANCE FROM ICPP IN KM (MI)	OPERATIONS PER YEAR [N]	ICPP AREA IN KM ² (MI ²) [A]	UPPER BOUND FATAL CRASH RATE PER KM (PER MI)	UPPER BOUND FREQUENCY PER YEAR [C*N*A]
PTI HELICOPTER 3.2-4.8 KM (2-3 MI)	5 (3)	800	0.49 (0.19)	1.0E-8 (2.7E-8)	4E-6
PTI HELICOPTER 4.8-6.4 KM (3-4 MILES)	5 (3)	800	0.49 (0.19)	6.6E-9 (1.7E-8)	3E-6
FAA AIRCRAFT TESTS	2.5 (1.5)	288	0.49 (0.19)	2.1E-8 (5.4E-8)	3E-6

4.3 EFFECTIVE TARGET AREA

In the previous ICPP crash frequency calculations, the target area has been the ICPP fenced area, which is actually larger than any one facility horizontal cross-sectional area. This section provides the effective target area for the various ICPP structures and the buildings that may contain radiological materials storage as aircraft crash radiological release targets.

In tables 19 and 20, effective target areas are calculated for individual buildings at the ICPP based upon the sum of the shadow area, skid area, and expanded areas. The ratio of the sum of these three areas to the area of the ICPP is provided for comparison and use in crash frequency calculations.

The crash frequency rates for each facility for both the PTI helicopter and the FAA aircraft tests are listed in table 21. No single facility has a crash rate above the incredible level. However, aggregate areas at the ICPP for radiological materials storage facilities, major processing facilities, and the ICPP site area have rates higher than incredible. These rates are listed in table 22.

Of the crash rates listed in table 22, those associated with the radiological materials storage facilities are the most important relative to safety analysis because of the concern about a potential release of these materials. Flying the PTI helicopter directly over these radiological material storage facilities is not a concern because the crash rate is lower than incredible. The crash rates are higher than incredible for flying the FAA aircraft adjacent to the ICPP and the landings and takeoffs of the PTI helicopter near the ICPP.

The PTI helicopter airport scenario concerning landings and takeoffs could be reduced to incredible by 1) relocating the landing pad farther from the ICPP as shown in table 23 or by restricting landings and takeoffs to a direction away from the ICPP, 2) restricting the flight direction, which would reduce the frequency by about half, and 3) moving

the landing pad to 6.4 km (4 mi) from the ICPP, which would reduce the crash frequency to less than a quarter of the calculated rate.

The airport scenario for the FAA aircraft tests crash rate of $7.8 \times 10^{-6}/y$ for the entire ICPP would be reduced to incredible if the flights were restricted to once every 8 years. The aggregate areas for ICPP major processing facilities and the ICPP site area include other

Table 19. Facility Area Ratio with the ICPP Area for Turbine Helicopters

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WING SPAN = 12 M (39 FT), SKID LENGTH = 100 M (328 FT), IMPACT ANGLE = 20°						
BLDG	ANGLE FROM PARALLEL	BUILDING TARGET AREA [M ² (FT ²)]			TOTAL EFFECTIVE	AREA RATIO
		EXPANDED	SKID	SHADOW		
ICPP [total area]	NA	NA	NA	NA	501,676 (5,400,000)	1.000
CPP-601 Processing Bldg	26	3,032 (32,635)	9,234 (99,390)	2,939 (31,637)	15,205 (163,662)	0.030
CPP-602 Lab Bldg	41	3,091 (33,268)	7,997 (86,077)	1,005 (10,815)	12,092 (130,160)	0.024
CPP-627 Remote Analytical Facility	45	1,181 (12,713)	5,002 (53,844)	880 (9,471)	7,063 (76,028)	0.014
CPP-640 Headend Processing	38	933 (10,039)	4,564 (49,123)	1,300 (13,990)	6,796 (73,153)	0.014
CPP-659 NWCF	33	4,302 (46,303)	9,984 (107,466)	3,596 (38,708)	17,882 (192,477)	0.036
CPP-604 Waste Treatment	31	1,977 (21,283)	6,937 (74,667)	2,324 (25,018)	11,238 (120,968)	0.022
CPP-605 Waste Treatment	36	542 (5,835)	3,597 (38,716)	1,205 (12,972)	5,344 (57,523)	0.011
CPP-603 Decon Area South	38	115 (1,241)	1,950 (20,990)	588 (6,330)	2,653 (28,561)	0.005

Table 19. (Contd.) Facility Area Ratio with the ICPP Area for
Turbine Helicopters

Page 2 of 2

WING SPAN = 12 M (39 FT). SKID LENGTH = 100 M (328 FT). IMPACT ANGLE = 20°						
BLDG	ANGLE FROM PARALLEL	BUILDING TARGET AREA [M ² (FT ²)]			TOTAL EFFECTIVE	AREA RATIO
		EXPANDED	SKID	SHADOW		
RADIOLOGICAL MATERIALS STORAGE FACILITIES						
CPP-603 Fuel Receiving and Storage	13	804 (8,657)	7,325 (78,850)	2,209 (23,778)	10,339 (111,285)	0.021
CPP-603 Storage Basin North and Middle	39	797 (8,582)	4,234 (45,569)	0 (0)	5,031 (54,151)	0.010
CPP-603 Storage Basin South	30	669 (7,196)	4,196 (45,169)	0 (0)	4,865 (52,365)	0.010
CPP-651 Unirradiated Fuel Storage	43	398 (4,285)	3,064 (32,982)	0 (0)	3,462 (37,267)	0.007
CPP-603 Graphite Fuel Storage	36	15,020 (16,172)	5,792 (62,349)	1,747 (18,802)	9,042 (97,323)	0.018
CPP-708 Main Stack	0	110 (1,180)	1,798 (19,352)	3,765 (40,525)	5,672 (61,057)	0.011
CPP-749 Peach Bottom Fuel Storage	43	12,801 (137,788)	16,069 (172,970)	0 (0)	28,870 (310,758)	0.058
Fast	15	3,769 (40,572)	14,680 (158,013)	5,902 (63,532)	24,351 (262,117)	0.049
Fifth Bin Set	45	114 (1,227)	1,921 (20,678)	0 (0)	2,035 (21,904)	0.004
Sixth Bin Set	45	658 (7,085)	3,817 (41,088)	0 (0)	4,475 (48,173)	0.009
Seventh Bin Set	45	658 (7,085)	3,817 (41,088)	0 (0)	4,475 (48,173)	0.009
Tank Farm area	35	21,317 (229,451)	21,709 (233,669)	0 (0)	43,025 (463,120)	0.086
FACILITY TOTALS	NA	NA	NA	NA	223,917 (2,410,224)	0.446
TOTAL - RADIOLOGICAL MATERIALS STORAGE FACILITIES	NA	NA	NA	NA	145,643 (1,567,693)	0.290

Table 20. Facility Area Ratio with the ICPP Area for Air Carriers

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WING SPAN = 60 M (197 FT), SKID LENGTH = 500 M (1640 FT), IMPACT ANGLE = 20°						
BLDG	ANGLE FROM PARALLEL	BUILDING TARGET AREA [M ² (FT ²)]			TOTAL EFFECTIVE	AREA RATIO
		EXPANDED	SKID	SHADOW		
ICPP [total area]	NA	NA	NA	NA	501,676 (5,400,000)	1
CPP-601 Processing Bldg	27	6,003 (64,614)	70,213 (755,762)	4,469 (48,100)	80,684 (868,477)	0.161
CPP-602 Lab Bldg	41	6,334 (68,180)	64,073 (689,680)	1,610 (17,327)	72,017 (775,187)	0.144
CPP-627 Remote Analytical Facility	45	3,018 (32,488)	49,097 (528,474)	1,727 (18,588)	53,842 (579,550)	0.107
CPP-640 Headend Processing	38	2,500 (26,914)	46,904 (504,866)	2,671 (28,750)	52,075 (560,530)	0.104
CPP-659 NWCF	33	8,085 (87,030)	74,012 (796,654)	5,330 (57,374)	87,427 (941,058)	0.174
CPP-604 Waste Treatment	32	4,395 (47,305)	58,745 (632,331)	3,936 (42,363)	67,076 (721,999)	0.134
CPP-605 Waste Treatment	37	1,645 (17,711)	42,061 (452,744)	2,818 (30,331)	46,525 (500,787)	0.093
CPP-603 Decon Area South	39	472 (5,076)	33,830 (364,145)	2,040 (21,956)	36,342 (391,177)	0.072
RADIOLOGICAL MATERIALS STORAGE FACILITIES						
CPP-603 Fuel Receiving and Storage	14	1,939 (20,875)	60,667 (653,010)	3,658 (39,373)	66,264 (713,258)	0.132
CPP-603 Storage Basin North and Middle	39	2,221 (23,904)	45,252 (487,091)	0 (0)	47,473 (510,995)	0.095
CPP-603 Storage Basin South	31	1,903 (20,487)	45,051 (484,920)	0 (0)	46,954 (505,408)	0.094
CPP-651 Unirradiated Fuel Storage	43	1,299 (13,987)	39,404 (424,139)	0 (0)	40,703 (438,126)	0.081
CPP-603 Graphite Fuel Storage	36	3,590 (38,646)	53,049 (571,012)	3,199 (34,429)	59,838 (644,087)	0.119
CPP-708 Main Stack	0	403 (4,340)	33,071 (355,971)	13,847 (149,051)	47,321 (509,362)	0.094
CPP-749 Peach Bottom Fuel Storage	43	19,947 (214,713)	104,447 (1,124,257)	0 (0)	124,394 (1,338,969)	0.248
Fast	16	6,639 (71,464)	97,381 (1,048,197)	7,829 (84,268)	111,849 (1,203,929)	0.223
5th Bin Set	45	467 (5,025)	33,687 (362,601)	0 (0)	34,154 (367,626)	0.068
6th Bin Set	45	1,925 (20,716)	43,170 (464,677)	0 (0)	45,094 (485,392)	0.090
7th Bin Set	45	1,925 (20,716)	43,170 (464,677)	0 (0)	45,094 (485,392)	0.090

Table 20. (Contd.) Facility Area Ratio with the ICPP Area for Air Carriers

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WING SPAN = 60 M (197 FT), SKID LENGTH = 500 M (1640 FT), IMPACT ANGLE = 20°						
BUILDING TARGET AREA [M ² (FT ²)]						
BLDG	ANGLE FROM PARALLEL	EXPANDED	SKID	SHADOW	TOTAL EFFECTIVE	AREA RATIO
FACILITY TOTALS	NA	NA	NA	NA	1,328,220 (14,296,840)	2.648
FACILITY TOTALS	NA	NA	NA	NA	1,328,220 (14,296,840)	2.648
TOTAL - RADIOLOGICAL MATERIALS STORAGE FACILITIES	NA	NA	NA	NA	832,232 (8,958,075)	1.659

Table 21. ICPP Facility Airplane Crash Rate per Year (upper bound)

BLDG	PTI HELICOPTER FREQUENCY PER YEAR				FAA AIRCRAFT TEST FREQUENCY PER YEAR	
	TLOC/Y (0 MI)	TLOC/Y (3 MI)	AIRPORT/Y (2-3 MI)	AIRPORT/Y (3-4 MI)	TLOC/Y	AIRPORT/Y
ICPP [total area]	2.2E-6	5.5E-9	4.1E-6	2.6E-6	2.1E-9	2.9E-6
CPP-601 Processing Bldg	6.8E-8	1.7E-10	1.2E-7	7.9E-8	3.4E-10	4.7E-7
CPP-602 Lab Bldg	5.4E-8	1.3E-10	9.8E-8	6.3E-8	3.1E-10	4.2E-7
CPP-627 Remote Analytical Facility	3.1E-8	7.8E-11	5.7E-8	3.7E-8	2.3E-10	3.2E-7
CPP-640 Headend Processing	3.0E-8	7.5E-11	5.5E-8	3.5E-8	2.2E-10	3.1E-7
CPP-659 NWCF	8.0E-8	2.0E-10	1.4E-7	9.3E-8	3.7E-10	5.1E-7
CPP-604 Waste Treatment	5.0E-8	1.2E-10	9.1E-8	5.9E-8	2.9E-10	3.9E-7
CPP-605 Waste Treatment	2.4E-8	5.9E-11	4.3E-8	2.8E-8	2.0E-10	2.7E-7
CPF-603 Decon Area South	1.2E-8	2.9E-11	2.1E-8	1.4E-9	1.5E-10	2.1E-7
RADIOLOGICAL MATERIALS STORAGE AREAS						
CPP-603 Fuel Receiving and Storage	4.6E-8	1.1E-10	8.3E-8	5.4E-8	2.8E-10	3.9E-7
CPP-603 Storage Basin North and Middle	2.2E-8	5.6E-11	4.1E-8	2.6E-8	2.0E-10	2.8E-7
CPP-603 Storage Basin South	2.2E-8	5.4E-11	3.9E-8	2.5E-8	2.0E-10	2.8E-7
CPP-651 Unradiated Fuel Storage	1.5E-8	3.8E-11	2.8E-8	1.8E-8	1.7E-10	2.4E-7
CPP-603 Graphite Fuel Storage	4.0E-8	1.0E-10	7.3E-8	4.7E-8	2.6E-10	3.5E-7
CPP-708 Main Stack	2.5E-8	6.3E-11	4.6E-8	3.0E-8	2.0E-10	2.8E-7
CPP-749 Peach Bottom Fuel Storage	1.3E-7	3.2E-10	2.3E-7	1.5E-7	5.3E-10	7.3E-7
Fast	1.1E-7	2.7E-10	2.0E-7	1.3E-8	4.8E-10	6.6E-7
Fifth Bin Set	9.1E-9	2.2E-11	1.6E-8	1.1E-9	1.5E-10	2.0E-7
Sixth Bin Set	2.0E-8	4.9E-11	3.6E-8	2.3E-8	1.9E-10	2.6E-7
Seventh Bin Set	2.0E-8	4.9E-11	3.6E-8	2.3E-8	1.9E-10	2.6E-7
Tank Farm area	1.9E-7	4.8E-10	3.5E-7	2.2E-7	7.0E-10	9.6E-7
FACILITY TOTALS	1.0E-6	2.5E-9	1.8E-6	1.2E-6	5.7E-9	7.8E-6
TOTAL - RADIOLOGICAL MATERIALS STORAGE AREAS	6.5E-7	1.6E-9	1.2E-6	7.6E-7	3.5E-9	4.9E-6

Table 22. ICPP Facility Airplane Crash Rate per Year

PTI HELICOPTER FREQUENCY PER YEAR				
BLDG	TLOC/Y (0 MI)	ALLOWABLE HELICOPTER TRIPS		
ICPP (TOTAL AREA)	2.2E-06	358		
PROCESSING FACILITIES TOTAL	1.0E-06	801		
RADIOLOGICAL MATERIALS STORAGE FACILITIES TOTAL	6.5E-07	1232		
PTI HELICOPTER FREQUENCY PER YEAR				
	AIRPORT/Y (2-3 MI)	ALLOWABLE HELICOPTER TRIPS	AIRPORT/Y (3-4 MI)	ALLOWABLE HELICOPTER TRIPS
ICPP AREA	4.0E-6	198	2.6E-6	306
PROCESSING FACILITIES TOTAL	1.8E-6	443	1.2E-6	686
RADIOLOGICAL MATERIALS STORAGE FACILITIES TOTAL	1.2E-6	681	7.6E-7	1054
FAA TESTS FREQUENCY PER YEAR				
	AIRPORT/Y	ALLOWABLE FAA FLIGHTS	ALLOWABLE YEARS BETWEEN TESTS	
ICPP AREA	2.9E-06	49	3	
PROCESSING FACILITIES TOTAL	7.8E-06	18	8	
RADIOLOGICAL MATERIALS STORAGE FACILITIES TOTAL	4.9E-6	29	5	

Table 23. Crash Frequencies Reduction Factors by Airport Distance

AIRPORT DISTANCE FROM ICPP IN KM (MI)	FATAL CRASHES PER KM ² (PER MI ²)	FREQUENCY REDUCTION FACTOR			PROCESSING FACILITY		RADIOLOGICAL MATERIALS STORAGE FACILITIES	
			ICPP TOTAL FREQUENCY/Y	REDUCED FREQUENCY/Y	TOTAL FREQUENCY/Y	REDUCED FREQUENCY/Y	TOTAL FREQUENCY/Y	REDUCED FREQUENCY/Y
3.2-4.8 (2-3)	1.0E-6 (2.7E-8)	1.00	4.0E-6	4.0E-6	1.8E-6	1.8E-6	1.2E-6	1.2E-6
4.8-6.4 (3-4)	6.6E-9 (1.7E-8)	0.65	4.0E-6	2.6E-6	1.8E-6	1.2E-7	1.2E-6	7.6E-7
6.4-8 (4-5)	2.3E-9 (6.0E-9)	0.22	4.0E-6	9.0E-7	1.8E-6	4.0E-7	1.2E-6	2.6E-7

buildings and areas of the ICPP. These crash rates have a greater crash rate than that for the PTI helicopter to crash into the aggregate area for radiological materials storage facilities. These rates are less than that for aircraft crashing into the aggregate ICPP site area during FAA testing. The larger effective area of facilities for the FAA tests is because of the FAA aircraft large skid and shadow areas used in the calculation of the effective target area. Summing all the individual facility effective areas produces a total greater than the area of the ICPP. The total rates are conservative because many of the ICPP facilities are adjacent to each other and would have overlapping effective target areas. The rates for the facility totals can be reduced to incredible by restricting the PTI helicopter to 443 flights per year and the FAA tests to either 18 aircraft flights per year or to testing once every 8 years.

The ICPP total crash rates can be reduced to incredible by restricting the PTI helicopter to 198 flights per year and the FAA tests to once every three years. Because FAA aircraft tests occur only once every few years, this rate when averaged over several years is essentially incredible.

Table 22 lists the total ICPP, total facilities, and total radiological materials storage facilities that are affected by the probabilities of a PTI helicopter crash. The crash rate can be reduced to incredible by restricting the number of flights over the structures to less than the allowable helicopter trips listed in the table. Restricting all helicopter flights over the ICPP to a maximum of 358 per year reduces the helicopter inflight rate to incredible for all areas of the ICPP.

The helicopter airport frequency in table 22 is bordering on incredible. The crash frequency can be reduced to incredible by restricting the number of flights to 317 per year. The airport assumption is that the flights around an airport are uniformly distributed in all directions. The risk, however, is greater in the direction the helicopter typically flies. Restricting takeoffs and landings to a direction away from the ICPP would also reduce this crash

frequency. Also, moving the helicopter pad farther away from the ICPP would reduce the crash frequency relative to the ICPP. The frequency for locating the helicopter pad farther away from the ICPP is shown in table 23. Locating the helicopter pad between 6.4 and 8 km (4 and 5 mi) away from the ICPP would reduce the frequency to an incredible level.

5. CONCLUSIONS

Based upon the results of this study, it can be concluded that any risk of aircraft crashing into ICPP structures is small. The crash frequency into the aggregate area for radiological materials storage facilities of FAA aircraft during test flights has the highest risk factor, which is $7.8\text{E-}6/\text{y}$. Restricting the FAA aircraft tests over radiological materials storage areas to once every five years would reduce the average frequency over several years to incredible.

The crash frequency of a PTI helicopter into the aggregate area for the radiological materials storage facilities while taking off or landing near the ICPP is $1.2 \times 10^{-6}/\text{y}$, which is close to the incredible level. The TLOC crash frequency of a PTI helicopter while flying directly over the ICPP is incredible relative to the radiological materials storage area. The small hazard from takeoff and landing can be reduced to incredible by 1) restricting flights toward the ICPP, 2) relocating the PTI landing and takeoff pad to 6.4 km (4 mi) from the ICPP, or 3) limiting helicopter flights to fewer than 681 flights per year.

The crash frequency of the PTI helicopter and the FAA aircraft into the aggregate area for ICPP major processing facilities or the ICPP site area can be reduced by restricting flights. Restricting PTI helicopter flights directly over the ICPP to fewer than 358 per year would reduce this rate to incredible. Restricting FAA tests to one in 8 years would reduce this crash rate to incredible.

The crash frequencies discussed above for aggregate areas are so close to incredible that none of the mitigative suggestions reduces the frequency by more than an order of magnitude to reach the incredible level. While the aggregate areas have crash rates higher than incredible, no single facility has a crash frequency above incredible. Therefore, aircraft crash scenarios are not required in safety analysis for any single facility. The PTI helicopter takeoff and landing scenario is a borderline-incredible co-located event relative to the identified aggregate areas of the ICPP site area, while the direct overflight in

incredible. This is because NRC methods use higher fatal accident rates for airport scenarios and the less common TLOC accident rate for overflights. This crash frequency is close enough to incredible that restricting landing site operations is a direction away from the ICPP would also reduce this to the incredible level. The FAA tests also are analyzed using the NRC airport scenario method, which gives a borderline-incredible crash frequency for aggregate areas. This crash frequency would be reduced to an incredible level by limiting the number of tests conducted.

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